SUMMARY

A lack of overwintering juvenile rearing habitat is most limiting to the ability of the habitat in the Entiat watershed to fully sustain salmon populations. This is a function of the alteration of the natural hydrologic and geomorphic processes in the watershed chiefly resulting from losses in floodplain connectivity and riparian zone conditions (USDA NRCS Stream Team, 1998; USFS, 1996; Rocky Reach Dam Hydroelectric Facility et al., 1998). Protection, rehabilitation and restoration of these habitats will presumably provide for other life cycle needs of salmonids, and fish and wildlife in general who are part of the Entiat watershed ecosystem.

Securing protection of stream channel sections anywhere in the watershed that presently allow unrestricted stream channel diversity and floodplain function is the principle means to meeting this objective. This can be accomplished in conservation easements, easements, or direct purchases. The following list, taken from Exhibit D - Aquatic Species and Habitat Assessment: Wenatchee, Entiat, Methow and Okanogan Watersheds (Rock Island Dam Hydroelectric Facility et al, 1998), identifies stream reaches which should receive protection order of priority :

1) Riparian bottom land and side channels in the Stillwaters Reach (between the terminal moraine and Preston Creek)
2) Riparian bottomland and side channels along the mainstem Entiat between Preston Creek and Fox Creek
3) Riparian bottomlands in the lower Mad River, Stormy Creek and Roaring Creek

Rehabilitation of altered stream reaches to increase functional overwintering juvenile rearing habitat is a second strategy. Engineered, structural instream improvements like bankside rootwad placements, rock weir placements, bioengineered riparian plantings, and many others offer short term improvements but maintenance costs may be substantial given the natural frequency of fires and floods in this watershed. The only realistic means to accomplish this is to have a combined short-term/long-term strategy (Rock Island Dam Hydroelectric Facility et al, 1998), Initially the focus should be structurally engineered and designed improvements like anchored large woody debris (LWD), boulder placement and side channel constructions. The long term approach is to secure riparian habitat in the Entiat watershed downstream of the Mad River confluence through conservation easements, easements, or direct purchases. This would allow for the recovery of the natural hydrologic and geomorphic processes. This recovery may be accelerated by implementing projects in the acquired riparian habitat which are designed to restore floodplain access and reestablish multi-species, multi-age class, native plant communities.

Unscreened and inadequately screened surface water diversions (pumps and ditches) and improperly designed water diversions and dams pose a direct threat to salmonids. Placement or repair of properly functioning screens, and proper design and placement of surface water diversions, should also be considered as structural improvements that can result in a direct improvement to juvenile fish survival.

BACKGROUND

This report is an assessment of the habitat-related factors limiting the ability of the habitat to fully sustain salmon populations in the Entiat watershed, also know as Water Resource Inventory Area (WRIA) 46. It was written pursuant to Engrossed Substitute House Bill (ESHB) 2496 (RCW 75.46), the Salmon Recovery Act, a key piece of the 1998 Legislature's salmon recovery effort.

Engrossed Substitute House Bill (ESHB) 2496 in part:

- directs the Conservation Commission in consultation with local government and the tribes to invite private, federal, state, tribal and local government personnel with appropriate expertise to act as a technical advisory group;

- directs the technical advisory group to identify limiting factors for salmonids to respond to the limiting factors relating to habitat pursuant to section 8 sub 2 of this act;

- defines limiting factors as "conditions that limit the ability of habitat to fully sustain populations of salmon."

- defines salmon as all members of the family salmonidae which are capable of self-sustaining, natural production.

The overall goal of the Conservation Commission's limiting factors project is to identify habitat factors limiting production of salmon in the state. In waters shared by salmon, steelhead and bull trout we will include all three. Later, we will add bull trout only waters.

It is important to note that the responsibilities given to the Conservation Commission in ESHB 2496 do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of identifying limiting factors are being dealt with in other forums.

The Relative Role of Habitat in Healthy Populations of Natural Spawning Salmon

During the last 10,000 years, Washington State anadromous salmonid populations have evolved in their specific habitats (Miller, 1965). Water chemistry, flow, and the physical stream components unique to each stream have helped shaped the characteristics of each salmon population. These unique physical attributes have resulted in a wide variety of distinct salmon stocks for each salmon species throughout the State. Within a given species, stocks are population units that do not extensively interbreed because returning adults rely on a stream's unique chemical and physical characteristics to guide them to their natal grounds to spawn. This maintains the separation of stocks during reproduction, thus preserving the distinctiveness of each stock.

Throughout the salmon's life cycle, the dependence between the stream and a stock continues. Adults spawn in areas near their own origin because survival favors those that do. The timing of juveniles leaving the river and entering the estuary is tied to high natural river flows. It has been theorized that the faster speed during out-migration reduces predation on the young salmon and perhaps is coincident to favorable feeding conditions in the estuary (Wetherall, 1971). These are a few examples that illustrate how a salmon stock and its environment are intertwined throughout the entire life cycle.

Salmon habitat includes the physical, chemical and biological components of the environment that support salmon. Within freshwater and estuarine environments, these components include water quality, water quantity or flows, stream and river physical features, riparian zones, upland terrestrial conditions, and ecosystem interactions as they pertain to habitat. However, these components closely intertwine. Low stream flows can alter water quality by increasing temperatures and decreasing the amount of available dissolved oxygen, while concentrating toxic materials. Water quality can impact stream conditions through heavy sediment loads, which result in a corresponding increase in channel instability and decrease in spawning success. The riparian zone interacts with the stream environment, providing nutrients and a food web base, woody debris for habitat and flow control (stream features), filtering runoff prior to surface water entry (water quality), and providing shade to aid in water temperature control.

Salmon habitat includes clean, cool, well-oxygenated water flowing at a normal (natural) rate for all stages of freshwater life. In addition, salmon survival depends upon specific habitat needs for egg incubation, juvenile rearing, migration of juveniles to saltwater, estuary rearing, ocean rearing, adult migration to spawning areas, and spawning. These specific needs can vary by species and even by stock.

When adults return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools with vegetative cover and instream structures such as root wads for resting and shelter from predators. Successful spawning and incubation depend on sufficient gravel of the right size for that particular population, in addition to the constant need of adequate flows and water quality, all in unison at the necessary location. Also, delayed upstream migration can be critical. After entering freshwater, most salmon have a limited time to migrate and spawn, in some cases, as little as 2-3 weeks. Delays can results in pre-spawning mortality, or spawning in a suboptimum location.

After spawning, the eggs need stable gravel that is not choked with sediment. River channel stability is vital at this life history stage. Floods have their greatest impact to salmon populations during incubation, and flood impacts are worsened by human activities. In a natural river system, the upland areas are forested, and the trees and their roots stores precipitation, which slows the rate of storm water into the stream. The natural, healthy river is sinuous and contains large pieces of wood contributed by an intact, mature riparian zone. Both slow the speed of water downstream. Natural systems have floodplains that are connected directly to the river at many points, allowing wetlands to store flood water and later discharge this storage back to the river during lower flows. In a healthy river, erosion or sediment input is great enough to provide new gravel for spawning and incubation, but does not overwhelm the system, raising the riverbed and increasing channel instability. A stable incubation environment is essential for salmon, but is a complex function of nearly all habitat components contained within that river ecosystem.

Once the young fry emerge from the gravel nests, certain species such as chum, pink, and some chinook salmon quickly migrate downstream to the estuary. Other species, such as coho, steelhead, bulltrout, and chinook, will search for suitable rearing habitat within the side sloughs and channels, tributaries, and spring-fed "seep" areas, as well as the outer edges of the stream. These quiet-water side margin and off channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring. Most sockeye populations migrate from their gravel nests quickly to larger lake environments where they have unique habitat requirements. These include water quality sufficient to produce the necessary complex food web to support one to three years of salmon growth in that lake habitat prior to outmigration to the estuary.

As growth continues, the juvenile salmon (parr) move away from the quiet shallow areas to deeper, faster areas of the stream. These include coho, steelhead, bulltrout, and certain chinook. For some of these species, this movement is coincident with the summer low flows. Low flows constrain salmon production for stocks that rear within the stream. In non-glacial streams, summer flows are maintained by precipitation, connectivity to wetland discharges, and groundwater inputs. Reductions in these inputs will reduce that amount of habitat; hence the number of salmon dependent on adequate summer flows.

In the fall, juvenile salmon that remain in freshwater begin to move out of the mainstems, and again, off-channel habitat becomes important. During the winter, coho, steelhead, bulltrout, and remaining chinook parr require habitat to sustain their growth and protect them from predators and winter flows. Wetlands, stream habitat protected from the effects of high flows, and pools with overhead are important habitat components during this time.

Except for bulltrout and resident steelhead, juvenile parr that have converted to smolts begin migrating downstream towards the estuary. Again, flows are critical, and food and shelter are necessary. The natural flow regime in each river is unique, and has shaped the population's characteristics through adaptation over the last 10,000 years. Because of the close inter-relationship between a salmon stock and its stream, survival of the stock depends heavily on natural flow patterns.

The estuary provides an ideal area for rapid growth, and some salmon species are heavily dependent on estuaries, particularly chinook, chum, and to a lesser extent, pink salmon. Estuaries contain new food sources to support the rapid growth of salmon smolts, but adequate natural habitat must exist to support the detritus-based food web, such as eelgrass beds, mudflats, and salt marshes. Also, the processes that contribute nutrients and woody debris to these environments must be maintained to provide cover from predators and to sustain the food web. Common disruptions to these habitats include dikes, bulkheads, dredging and filling activities, pollution, and alteration of downstream components such as lack of woody debris and sediment transport.

All salmonid species need adequate flow and water quality, spawning riffles and pools, a functional riparian zone, and upland conditions that favor stability, but some of these specific needs vary by species, such as preferred spawning areas and gravel. Although some overlap occurs, different salmon species within a river are often staggered in their use of a particular type of habitat. Some are staggered in time, and others are separated by distance.

Chum and pink salmon use the streams the least amount of time of any salmonid in Washington state and do not occur in the Mid-Columbia Region.

Chinook salmon have three major run types in Washington State – spring, summer and fall runs. Summer and fall runs of chinook are referred to as an "ocean-type" (Healey, 1983) meaning they spend less than one year in freshwater before migrating to the ocean as subyearlings. Most of their life is therefore spent in the ocean; spring chinook are considered "stream-type" (spending one or more years in freshwater). However, there is evidence that some subyearling summer chinook exhibit a slow rearing migration and forage behavior as they pass the reservoir system, thereby delaying their arrival at the estuaries until they are yearlings and of a larger size. The extent to which this is a phenomenon of the dam system or a natural influence is not known. Chapman et al. (1994) states that there is a lack of information to predict whether subyearlings survive better if they reach the estuary early and at small size, or if they remain in reservoirs and grow before reaching the estuary.

Relative to run types, in the Mid-Columbia Region biologists have not detected significant genetic differences between the summer and fall runs; they are usually just referred to as summer chinook salmon or summer/fall chinook salmon (Chapman et al., 1994). Thus, these summer and fall chinook are not reproductively isolated (Federal Register 9/23/94). Rather, they are part of a larger Evolutionarily Significant Unit (ESU) that includes all late-run (summer and fall) ocean-type chinook salmon from the mainstem Columbia River and its tributaries (excluding the Snake River) between Chief Joseph and McNary dams (Waknitz et al., 1995). They are lumped into "late-run" chinook by the National Marine Fisheries Service (NMFS) and for the purposes of this document will be discussed as late-run chinook.

Adult late-run chinook begin Columbia River entry in late May to early June (Mullan, 1987). They generally spawn from late September to mid-November. Eggs remain in the gravels over winter until emergence in mid-February through April. Outmigration from the natal tributaries has been strongly correlated to a subyearling size of about 80mm in length where growth rate is a factor of water temperature (Chapman et al, 1994). This is assuming adequate holding areas for fry. Therefore, timing of subyearlings outmigration from the mid-Columbia River tributaries is highly variable and occurs over a broad time period (February through August).

In the Mid-Columbia Region, juvenile spring chinook salmon (early-run) generally spend one year in freshwater before they migrate downstream (Mullan, 1987; Healey, 1991); most spend two years in the ocean before migrating back to their natal streams (Mullan, 1987). The adults enter the tributaries to the mid-Columbia River from late April through July, and hold in the deeper pools and under cover until onset of spawning. They may spawn near their holding areas or move upstream into smaller tributaries. Spawning occurs from late July in the upstream reaches, and continues downstream through September, usually peaking in late August (Chapman et al, 1995a). The eggs then remain over winter where they were laid in the gravels, with the young (fry) emerging that following spring in April and May (Peven 1992). These same young will remain in freshwater environments, not migrating out as smolts until the following spring. This extended period spent in the freshwater environment, both as adults and juveniles, makes spring chinook salmon typically more susceptible than the summer/fall (late-run) chinook salmon to impacts from habitat alterations that occur in the tributaries. Low flows in some areas, whether the result of natural or human-induced occurrences have a deleterious effect upon spring chinook salmonid spawning distribution, incubation survival, and late summer rearing habitat quality (Chapman et al, 1995a).

Coho salmon have been extirpated from the Mid-Columbia River Region despite plantings of 46 million fry, fingerlings, and smolts from mid-Columbia River fish hatcheries between 1942 and 1975 (YIN et al., 1999). Because the historical stocks of coho were decimated in this region near the turn of the century, most life history information was obtained through affidavits from older residents. The historical information supports the fact that these fish were probably early-returning-type adults, ascending the mid-Columbia tributaries in August and September (Mullan, 1983).

In the rest of Washington state, the onset of coho salmon spawning is tied to the first significant fall freshet. They typically enter freshwater from September to early December, but has been observed as early as late July and as late as mid-January (WDF et al, 1993). They often mill near the river mouths or in lower river pools until freshets occur. Spawning usually occurs between November and early February, but is sometimes as early as mid-October and can extend into March. Spawning typically occurs in tributaries and sedimentation in these tributaries can be a problem, suffocating eggs. As chinook salmon fry exit the shallow low-velocity rearing areas, coho fry enter the same areas for the same purpose. As they grow, juveniles move into faster water and disperse into tributaries and areas which adults cannot access (Neave, 1949). Pool habitat is important not only for returning adults, but for all stages of juvenile development. Preferred pool habitat includes deep pools with riparian cover and woody debris.

All coho juveniles remain in the river for a full year after leaving the gravel nests, but during the summer after early rearing, low flows can lead to problems such as a physical reduction of available habitat, increased stranding, decreased dissolved oxygen, increased temperature, and increased predation. Juvenile coho are highly territorial and can occupy the same area for a long period of time (Hoar, 1958). The abundance of coho can be limited by the number of suitable territories available (Larkin, 1977). Streams with more structure (logs, undercut banks, etc.) support more coho (Scrivener and Andersen, 1982), not only because they provide more territories (useable habitat), but they also provide more food and cover. There is a positive correlation between their primary diet of insect material in stomachs and the extent the stream was overgrown with vegetation (Chapman, 1965). In addition, the leaf litter in the fall contributes to aquatic insect production (Meehan et al, 1977).

In the autumn as the temperatures decrease, juvenile coho move into deeper pools, hide under logs, tree roots, and undercut banks (Hartman, 1965). The fall freshets redistribute them (Scarlett and Cederholm, 1984), and over-wintering generally occurs in available side channels, spring-fed ponds, and other off-channel sites to avoid winter floods (Peterson, 1980). The lack of side channels and small tributaries may limit coho survival (Cederholm and Scarlett, 1981). As coho juveniles grow into yearlings, they become more predatory on other salmonids. Coho begin to leave the river a full year after emerging from their gravel nests with the peak outmigration occuring in early May. Coho use estuaries primarily for interim food while they adjust physiologically to saltwater.

Sockeye salmon have a wide variety of life history patterns, including landlocked populations of kokanee which never enter saltwater. The distribution of sockeye salmon in the Mid-Columbia Region is limited to lakes Wenatchee (Wenatchee watershed) and Osoyoos (Okanogan watershed). Limited numbers of adults and juveniles are periodically detected however, in the Methow and Entiat rivers (Carie, 1996) and in isolated areas of the mid-Columbia River (Chapman et al, 1995b). Of the populations that migrate to sea, adult freshwater entry varies from spring for the Quinault stock, summer for Ozette stock, to June for mid-Columbia River stocks, and summer and fall for Puget Sound stocks. Spawners reach Wenatchee and Osoyoos lakes during July - September (Mullan, 1986). Both sockeye populations from the mid-Columbia basin begin spawning in September, with activity peaking in the Wenatchee system about the third week of September, and approximately a month later in the Okanogan River (Howell et al, 1985). Statewide, spawning ranges from September through February, depending on the stock.

Sockeye spawning habitat varies widely. Some populations spawn in rivers (Cedar River) while other populations will also use the beaches of their natal lake (Lake Wenatchee), typically in areas of upwelling groundwater. The spawning beaches along lakes provide a unique habitat that is often altered by human activities, such as pier and dock construction, dredging, and weed control. Sockeye also spawn in side channels and spring-fed ponds. Principal spawning areas for Wenatchee River sockeye are in the lower 5.6 km (3.6 miles) of the Little Wenatchee River and in the lower 8 km (4.8 miles) of the White River. Okanogan River sockeye spawn in the mainstem Okanogan River from the head of Lake Osoyoos to the upstream outlet of Vaseux Lake in Canada (Howell et al, 1985).

In the Mid-Columbia Region, after sockeye fry emerge from the gravel in early to late spring they move to the nursery lake for rearing, although some types of fry in western Washington migrate directly to the sea. Most sockeye reside in lakes Osoyoos and Wenatchee until the following spring although some remain for an additional year. Lake rearing in populations statewide ranges from 1-3 years. In the spring after lake rearing is completed, juveniles migrate to the ocean where more growth occurs prior to adult return for spawning 1 to 3 (most 2 years) later (Schwartzbert and Fryer, 1988).

Steelhead have the most complex life history patterns of any Pacific salmonid species (Shapovalov and Taft, 1954). In Washington, there are two major run types, winter and summer steelhead, depending on when they enter freshwater. Winter steelhead adults begin river entry in a mature reproductive state in December and generally spawn from February through May. Dominating inland areas such as the Columbia Basin, summer steelhead adults enter the river from about May through October with spawning occurring the following spring from about February through April. In the mid-Columbia River region, steelhead are all summer-run fish and spawning occurs between March and June, but has been know to occur as late as July (Fish and Hanavan, 1948).

Fry emerge in late spring to August and begin dispersing downstream. In Washington, those juveniles that are anadromous (migrate to the ocean) usually spend 1-3 years in freshwater, with the greatest proportion spending two years (Busby et al, 1996). Peven (1990) has reported naturally produced juveniles in the mid-Columbia River tributaries spending between 1-7 years in freshwater before migrating to the ocean in April and May. This extended period of freshwater residency places a heavy reliance by steelhead on freshwater habitat conditions.

In addition to the above-described relationships between various salmon species and their habitats, there are also interactions between the species that have evolved over the last 10,000 years such that the survival of one species might be enhanced or impacted by the presence of another. Pink and chum salmon fry are frequently food items of coho smolts, Dolly Varden charr, and steelhead (Hunter, 1959). Chum fry have decreased feeding and growth rates when pink salmon juveniles are abundant (Ivankov and Andreyev, 1971), probably the result of occupying the same habitat at the same time (competition). These are just a few examples.

Most streams in Washington are home to several salmonid species, which together, rely upon freshwater and estuary habitat the entire calendar year. As the habitat and salmon review indicated, there are complex interactions between different habitat components, between salmon and their habitat, and between different species of salmon. For just as habitat dictates salmon types and production, salmon contribute to habitat and to other species.

Literature Cited

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F. W. Waknitz, and I.V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-27, 261 p.

Carie, D. G. 1996. Spring and summer chinook salmon and sockeye salmon spawning ground surveys on the Entiat River, 1995. U. S. Fish and Wildlife Service, Leavenworth, WA.

Cederholm, C.J. and W.J.. Scarlett. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981, p. 98-110. In: E.L. Brannon and W.O. Salo (eds.). Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington, Seattle, WA.

Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Am. Fish. Soc. 94:40-52.

Chapman, D.W., A. Giorgi, T. Hillman, D. Deppert, M. Erho, S. Hays, C. Peven, B. Suzumoto, R. Klinge. 1994. Status of summer/fall chinook salmon in the mid-Columbia Region. Don Chapman Consultants, Inc. Boise, ID, 411 p.

Chapman, D.W., and four authors. 1995a. Status of spring chinook salmon in the mid-Columbia Region. Don Chapman Consultants, Inc. Boise, ID.

Chapman, D.W., and seven authors. 1995b. Status of sockeye salmon in the mid-Columbia Region. Don Chapman Consultants, Inc. Boise, ID.

Fish, F. F. and M. G. Hanavan. 1948. A report on the Grand Coulee Fish Maintenance Project 1939 – 1947. USFWS, Spec. Rept. 55.

Hartman, G. F. 1965. The role of behaviour in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Board Can. 22:1035-1081.

Healey, M.C. 1983. Coastwide contribution and ocean migration patterns of stream-and ocean-type chinook salmon *Oncorhynchus tshawystcha*. Canandian Field Naturalist 97-427-433.

Healey, M. C. 1991. Life history of chinook salmon (*Oncorhynchus tshawystcha*). Pages 311 – 394 in C. Groot and L. Margolis, editors. Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, B.C.

Hoar, W.S. 1958. The evolution of migratory behaviour among juvenile salmon of the genus Oncorhynchus. J. Fish. Res. Board. Can. 15:391-428.

Howell, P., K. Jones, D Scarnecchia, L. LaVoy. W. Kendrea, and D. Ortmann. 1985. Stock assessment of Columbia River anadromous salmonids; Vol. 1: chinook, soho, chum, and sockeye salmon stock summaries. Rep. For Bonneville Power Administration, 83-335, Portland, OR.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Board Can. 16:835-886.

Ivankov, V.N. and V.L. Andreyev. 1971. The South Kuril chum (*Oncorhynchus keta*) ecology, population structure and the modeling of the population. J. Ichthyol. 11:511-524.

Larkin, P.A. 1977. Pacific Salmon, p. 156-186. In: J.A. Gulland (ed.). Fish population dynamics. J. Wiley & Sons, New York, NY.

Marshall, A.R., C. Smith, R. Brix, W. Dammers, J. Hymer, L. Lavoy. 1995. Genetic diversity units and major ancestral lineages for chinook salmon in Washington. In: Genetic Diversity Units and Major Ancestral Lineages of Salmonid Fishes in Washington. Wash. Dept. Fish and Wildlife. Technical Report Number RAD 95-02.

Meehan, W.R., F.J. Swanson, and J.R. Sedell. 1977. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. P. 137-145. In: R.R. Johnson and D. A. Jones (eds.). Importance, Preservation and Management of Riparian Habitat: A Symposium held at Tucson, Arizona, July 9, 1977. U.S. Forest Serv. Gen Tech. Rep. RM-43

Miller, R. R. 1965. Quaternary freshwater fishes of North America. In: The Quaternary of the United States. Princeton University Press, Princeton, New Jersey. Pp. 569-581.

Mullan, J.W. 1983. Overview of artificial and natural propagation of coho salmon (*Onchorhynchus kisutch*) on the mid-Columbia river. Fisheries Assistance Office, U.S. Fish and Wildlife Service, Leavenworth, WA.

Mullan, J.W. 1986. Determinants of sockeye salmon abundance in the Columbia River, 1880's – 1982: a review and synthesis. USFWS Biological Report 86(3), 111p.

Mullan, J. W. 1987. Status and propagation of chinook salmon in the mid-Columbia River through 1985. U. S. Fish and Wildl. Serv. Biol. Rep. 87(3), 111p.

Neave, F. 1949. Game fish populations of the Cowichan River. Bull. Fish. Res. Board Can. 84:1-32

Peterson, N.P. 1980. The role of spring ponds in the winter ecology and natural production of coho salmon (*Oncorhynchus kisutch*) on the Olympic Peninsula, Washington. M. Sc. Thesis. University of Washington Seattle, WA 96 p.

Peven, C. M. 1990. The life history of naturally produced steelhead trout from the mid-Columbia River Basin. MS these, University of Washington, Seattle.

Peven, C. M. 1992. Population status of selected stocks of salmonids from the mid-Columbia River Basin. Chelan County Public Utility District, Wenatchee, WA, 52 p.

Scarlett, W.J. and C.J. Cederholm. 1984. Juvenile coho salmon fall-winter utilization of two small tributaries of the Clearwater River, Jefferson County, Washington, p. 227-242. In: J.M. Walton and D. B. Houston (eds.). Proceedings of the Olympic Wild Fish

Conference, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Schwartzberg, M. and J. Fryer. 1988. Identification of Columbia basin sockeye salmon stocks based on scale pattern analyses, 1987. Tech. Rept. 88-2, Columbia River Inter-Tribal Fish Commission, Portland, OR.

Scrivener, J.C. and B.C. Andersen. 1982. Logging impacts and some mechanisms which determine the size of spring and summer populations of coho salmon fry in Carnation Creek, p. 257-272. In: G.F. Hartman (ed.) Proceedings of the Carnation Creek Workshop: a ten year review. Pacific Biological Station, Nanaimo, BC.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Onchorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game Fish Bull. 98, 375 p.

Simenstad, C.A. and E.O. Salo. 1982. Foraging success as a determinant of estuarine and near-shore carrying capacity of juvenile chum salmon (*Oncorhynchus keta*) in Hood Canal, Washington, p. 21-37. In: B.R. Meltreff and .A. Neve (eds.) Proceedings of the North Pacific Aquaculture Symposium. Alaska Sea Grant Rep. 82-2.

Waknitz, F. W., G. M. Matthews, T. Wainwright, and G. A. Winans. 1995. Status review for mid-Columbia River summer chinook salmon. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-22.

Washington Dept. Fisheries, Washington Dept. Wildlife, and Western Washington Indian Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory. Olympia, WA 212 p.

Washington Dept. Fisheries, Washington Dept. Wildlife, and Western Washington Indian Tribes. 1994. 1992 Washington State Salmon and Steelhead Stock Inventory. Appendices. Olympia, WA

Wetherall, J.A. 1971. Estimation of survival rates for chinook salmon during their downstream migration in the Green River, Washington. Doctoral dissertation. College of Fisheries, U. Wash. 170 p.

Withler, I.L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. J. Fish. Res. Board. Can. 23 (3): 365-393.

YIN (Yakama Indian Nation) and the Washington Department of Fish and Wildlife. 1999. Mid-Columbia Coho Salmon Reintroduction Feasibility Project, Preliminary